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RESEARCH ARTICLE

# Intelligence in Childhood and Atherosclerosis of the Carotid and Peripheral Arteries in Later Life: The Lothian Birth Cohort 1936

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**Data Availability Statement:** Due to ethical restrictions, data are available upon request from the Lothian Birth Cohort 1936 Study. To request the data, readers should contact the principal investigator, Ian Deary, who can be contacted at [i.deary@ed.ac.uk](mailto:i.deary@ed.ac.uk).

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## Abstract

### Objective

There is some evidence that people who score higher on tests of intelligence in childhood have lower carotid intima-media thickness and higher ankle brachial index in middle age. These findings need replicating in other, older populations. We investigated the prospective relationship between intelligence in childhood and atherosclerosis in the carotid and peripheral arteries at age 73 years.

### Methods

Participants were 713 members of the Lothian Birth Cohort 1936 whose intelligence was assessed at age 11 years. At age 73 years, carotid intima-media thickness and degree of stenosis were measured using ultrasound imaging; ankle-brachial index was measured using Doppler ultrasound.

### Results

There were no significant associations between intelligence at age 11 and measures of atherosclerosis at age 73. In age- and sex-adjusted analyses, for a standard deviation higher score in intelligence, intima-media thickness (x 10) was lower by 0.07 (-0.20, 0.06) mm and ankle brachial index (x 10) was lower by 0.09 (-0.24, 0.07); odds ratios for having carotid stenosis >25% or peripheral arterial disease were 0.98 (0.82, 1.16) and 1.05 (0.81, 1.36) respectively.

### Conclusion

In this study of people aged 73 years, higher childhood intelligence was not associated with reduced risk of atherosclerosis in the carotid or peripheral arteries.

collection and analysis, decision to publish, or preparation of the manuscript.

**Competing Interests:** The authors have declared that no competing interests exist.

## Introduction

There is consistent evidence that people who scored lower on tests of general cognitive ability in youth are more likely to develop coronary heart disease (CHD) as adults.[1–10] The explanation for these findings is unclear. They do not appear to be due to confounding by socioeconomic circumstances in early life. A few studies have been able to examine the potential mediating role of some established risk factors; in some of these studies such risk factors seem to account for very little of the association,[2, 6] but in others they account for a large part of it.[3, 9]

One potential mechanism linking intelligence in early life with later CHD risk might be atherogenesis. Atherosclerosis is a systemic, chronic inflammatory disorder that usually affects multiple parts of the arterial tree in the same individual. Measures of subclinical atherosclerosis such as carotid intima-media thickness (IMT) and ankle brachial index (ABI) correlate with severity and extent of coronary atherosclerosis[11, 12] and are consistently predictive of cardiovascular events.[13–15] Two recent longitudinal studies found evidence that lower intelligence in youth may increase susceptibility to atherogenesis. In the Newcastle Thousand Families Study, lower intelligence at age 11 years was associated with greater carotid IMT in men and women aged 49–51 years.[16] In the Vietnam Experience Study, male veterans who had scored lower on an intelligence test at conscription in early adulthood had a significantly lower mean ABI and were less likely to have peripheral arterial disease as indicated by an ABI  $\leq 0.90$  at around age 38 years.[17] However, since the major burden of CHD occurs in later life, these findings need replicating in other, older populations. There is also a need to examine the consistency of the relationship between intelligence in youth and atherogenesis in different parts of the arterial tree in the same sample. We used data from the Lothian Birth Cohort 1936 (LBC1936) to investigate the relationship between intelligence in childhood and atherosclerosis in the carotid and peripheral arteries at around age 73 years. One potential limitation in studying this relationship in people over age 70 is that lower intelligence is linked with earlier death [18] and with non-response[19, 20] so detecting an association may be difficult as individuals with lower intelligence may be under-represented in our sample.

## Methods

### Participants

The participants were members of the LBC1936.[21, 22] The study was set up to study cognitive ageing in surviving members of the Scottish Mental Survey of 1947. Between 2004 and 2007, individuals from the Lothian region of Scotland who might have taken part in the 1947 Survey were invited to participate in the LBC1936. The Lothian Community Health Index was used to identify 1936-born individuals, and media advertisements were used to inform people about the proposed study. The Lothian Community Health Index identified 3810 potential participants, and 3686 were invited to take part in the study. Overall, 2318 people responded, 1226 of whom were interested and eligible (97 of these people responded having seen the media advertisements). In total, 1,091 community-dwelling people took part in Wave 1 of the study when they were aged about 70 years. Wave 2 took place when participants were aged about 73 years; 866 people took part. Ethical approval was obtained from the Multi-Centre Ethics Committee for Scotland and Lothian Research Ethics Committee. All participants gave written informed consent.

### Measures

**Intelligence in childhood.** Most children born in 1936 and attending Scottish schools on 4<sup>th</sup> June 1947 took the Moray House Test No 12, a test of general intelligence, when they were

about age 11 years (mean 10.9, standard deviation 0.28) as part of the Scottish Mental Survey. The Moray House Test is a group-administered test with a predominance of verbal reasoning items and some numerical and spatial items. It was concurrently validated against the Terman-Merrill Revision of the Binet Scales.[23] The LBC1936 participants' scores on the test were corrected for age at testing and converted to an IQ scale with mean of 100, standard deviation (SD) 15.

**Atherosclerosis in the carotid and peripheral arteries.** At the Wave 2 interview, participants were invited to come back at a later date for neck artery ultrasound imaging. Of the 866 people who took part in Wave 2, 820 agreed to have ultrasound imaging. This was performed on a Siemens Antares Premium Colour Doppler scanner (Siemens AG, Erlangen, Germany) with 7.5 MHz variable frequency probe by one of two experienced neurovascular ultrasonographers; all scans were cross-checked by a consultant neuroradiologist. Representative velocity readings were obtained of the common, internal and external carotid arteries.[24] Percent stenosis was quantified based on velocity criteria and luminal reduction, expressed in North American Symptomatic Carotid Endarterectomy Trial format.[25] Common carotid and carotid bulb intima-media IMT was measured manually with callipers. Mean IMT was calculated using the average of three measurements made over a 1 cm long segment of the common carotid artery and carotid bulb.[26]

During a physical examination carried out at Wave 2, brachial systolic pressure was measured in the right arm after 5 min of rest using a Doppler ultrasound probe and a random zero sphygmomanometer placed just above the elbow. Ankle systolic pressure was measured in the posterior tibial artery of the right leg using a Doppler ultrasound probe and a random zero sphygmomanometer with the cuff position just above the malleolus. The ABI was derived by dividing the systolic blood pressure in the ankle by that in the arm. Peripheral arterial disease was defined as having an  $ABI \leq 0.90$ .

**Covariates.** We viewed father's social class in childhood as a potential confounder of any association between childhood intelligence and later life measures of atherosclerosis.[27] At Wave 1, participants provided information on their father's occupation when they were aged 11 years. Occupations were classified into six social class categories: professional, managerial, skilled non-manual, skilled manual, semi-skilled and unskilled. [28]

We viewed blood pressure, serum total cholesterol, glycosylated haemoglobin (HbA1c), smoking status, body mass index (BMI), and adult social class—all assessed at Wave 1—as potential mediators of any association between childhood intelligence and later life measures of atherosclerosis. Systolic and diastolic blood pressure were calculated as the average of three sitting readings taken using an Omron 705IT monitor. Blood samples (non-fasting) were taken during the participants' physical examination. Height and weight were measured with a portable stadiometer and electronic scales respectively. BMI was calculated as weight (in kilograms)/height (in metres)<sup>2</sup>. Adult socioeconomic position was derived from participants' (or their spouses') highest reported occupation and classified into categories as described above for father's occupation.

## Statistical analysis

We used ordinary least squares regression to examine differences in ABI according to a standard deviation (SD) increase in intelligence at age 11 years. Robust regression was used to examine differences in carotid IMT in relation to intelligence to reduce the effect of influential outliers. Logistic regression was used to examine risk of having peripheral arterial disease ( $ABI \leq 0.90$ ) or carotid stenosis  $>25\%$  in either the right or the left carotid arteries. Preliminary analyses showed that the relation between childhood intelligence and these measures of

**Table 1. Characteristics of the study participants (n = 713).**

	Mean (SD)	No (%)
Female		349 (49.0)
Age, years	72.5 (0.71)	
Father in professional/managerial social class in childhood		191 (26.8)
IQ at age 11 years	101.3 (14.9)	
Carotid IMT, mm	0.85 (0.20)	
Carotid stenosis>25%†		197 (29.0)
ABI*	1.09 (0.18)	
ABI≤90*		73 (11.7)

\*based on 654 people

†based on 680 people

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atherosclerosis did not differ by sex or age so we analysed men and women together and adjusted for sex and age. Analyses of carotid IMT, carotid stenosis and ABI are based on 713, 680 and 654 participants respectively who had data on childhood intelligence and father's social class (representing 82%, 79% and 76% respectively of those who took part in the Wave 2 follow-up).

## Results

[Table 1](#) shows the characteristics of the study participants.

[Table 2](#) shows the correlations between intelligence at age 11 years and carotid IMT, ABI, and maximum percent stenosis in either the right or left carotid artery. There were no statistically significant correlations between intelligence and any of these measures.

[Table 3](#) shows results of the regression analyses. In analyses adjusted for age and sex, there were no statistically significant associations between childhood intelligence and any measure of atherosclerosis in the carotid or peripheral arteries: for a standard deviation higher score in intelligence at age 11 years, intima-media thickness (x 10) was lower by 0.07 (-0.20, 0.06) mm and ankle brachial index (x 10) was lower by 0.09 (-0.24, 0.07); odds ratios for having carotid stenosis >25% or peripheral arterial disease were 0.98 (0.82, 1.16) and 1.05 (0.81, 1.36) respectively. Further adjustment for the potential confounding factor, father's social class in childhood, had little effect on the size of these associations.

We repeated our analyses of childhood intelligence in relation to ABI and peripheral arterial disease excluding those with an ABI > 1.4 (n = 32) in case arterial stiffness had produced falsely high levels, but this exclusion had little effect (data not shown).

In total, 9% of the participants had no data on father's social class in childhood. To check whether the restriction of the analytical sample to those with data on father's social class had

**Table 2. Correlations between intelligence at age 11 years and measures of atherosclerosis at age 73.**

	Intelligence	Carotid IMT	Maximum percent stenosis	ABI
Intelligence	-			
Carotid IMT	-0.056 (p = 0.14)	-		
Maximum percent stenosis	-0.057 (p = 0.13)	0.227 (p<0.001)	-	
ABI	-0.051 (p = 0.20)	-0.082 (p = 0.04)	-0.160 (p = 0.001)	-

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**Table 3. Results of regression analyses of measures of atherosclerosis in the carotid and peripheral arteries in relation to intelligence in childhood.**

	Carotid arteries		Peripheral arteries	
	Regression coefficient (95% CI for difference in carotid IMT (x10)	Odds ratio (95% CI) for carotid stenosis >25%	Regression coefficient (95% CI) for difference in ABI (x10)	Odds ratio (95% CI) for peripheral arterial disease
Intelligence, per SD increase, adjusted for:				
Sex and age	-0.07 (-0.20, 0.06)	0.98 (0.82, 1.16)	-0.09 (-0.24, 0.07)	1.05 (0.81, 1.36)
Sex, age and father's social class in childhood	-0.07 (-0.19, 0.06)	0.97 (0.81, 1.15)	-0.08 (-0.23, 0.08)	1.08 (0.83, 1.41)

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affected our estimates of the size of the associations between childhood intelligence and the measures of atherosclerosis, we repeated our analyses without this restriction. Associations were very similar in size to those reported in [Table 2](#).

Further adjustment for risk factors measured at Wave 1 that might potentially have mediated any association between childhood intelligence and later atherosclerosis, such as blood pressure, serum total cholesterol, smoking status, glycosylated haemoglobin, BMI, and adult social class had very little effect on the size of the associations (data not shown).

## Discussion

In this longitudinal study of older men and women whose intelligence had been assessed at age 11 years, we found no significant associations between intelligence in childhood and measures of atherosclerosis in the carotid or peripheral arteries at age 73 years. These findings contrast with results of two earlier studies in which lower intelligence in childhood or in early adulthood was associated with increased carotid IMT or lower ABI in middle-aged people.[\[16, 17\]](#)

One explanation for the inconsistency between the findings in the present study and those reported previously[\[16, 17\]](#) may lie with the age of our participants. Intelligence in childhood may be a more important risk factor for atherogenesis in adolescence and early to mid-adulthood than it is later in life. Some support for this comes from observations in another cohort that lower intelligence at age 11 was predictive of increased risk of cardiovascular disease, coronary heart disease and stroke in those who first experienced these events before age 65, but not in those who were over 65.[\[7\]](#) Data from repeated assessments of atherosclerosis in the same individuals over time are needed if we are to ascertain with accuracy whether the potential influence of childhood intelligence on atherogenesis diminishes with age. Another related explanation might be that those individuals who were particularly susceptible to the potential effect of childhood intelligence on atherogenesis—perhaps via its influences on health behaviours, blood pressure, or other cardiovascular risk factors[\[29–31\]](#)—were less likely to have survived to take part in this follow-up study. Unfortunately, we have no way of knowing whether this is the case because the cohort was only recruited when they were aged 70 so information on deaths that occurred prior to this age among people who would potentially have been eligible to participate is not available.

In view of the lack of association found in this study between childhood intelligence and measures of atherosclerosis in later life, we carried out a power calculation to assess whether our sample size was large enough to reliably show no association. To detect a correlation between childhood intelligence and IMT or ABI of -0.05 (the correlation found in our study) with 80% power using a one-sided 5%-level test would need a sample size of 2472, markedly larger than the sample of 713 on which our study was based.



Our findings suggest that higher intelligence in childhood is not associated with reduced atherogenesis in the carotid or peripheral arteries in people aged over 70. Further longitudinal studies are needed to establish the robustness of earlier observations linking lower intelligence in childhood or early adulthood with higher levels of atherosclerosis in the carotid or peripheral arteries in middle age and to investigate whether any such association persists with increasing age.

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## Author Contributions

Conceived and designed the experiments: IJD JW JMS MEB CRG EE AT. Performed the experiments: EE AT JW. Analyzed the data: CRG. Wrote the paper: CRG EE AT MEB JMS JW IJD.

## References

1. Silventoinen K, Modig-Wennerstad K, Tynelius P, Rasmussen F. Association between intelligence and coronary heart disease mortality: a population-based cohort study of 682 361 Swedish men. *Eur J Cardiovasc Prev Rehabil*. 2007; 14:555–60. PMID: [17667647](#)
2. Batty GD, Wennerstad KM, Smith GD, Gunnell D, Deary IJ, Tynelius P, et al. IQ in early adulthood and mortality by middle age: cohort study of 1 million Swedish men. *Epidemiology*. 2009; 20:100–9. doi: [10.1097/EDE.0b013e31818ba076](#) PMID: [19234402](#)
3. Hemmingsson T, Essen J, Melin B, Allebeck P, Lundberg I. The association between cognitive ability measured at ages 18–20 and coronary heart disease in middle age among men: a prospective study using the Swedish 1969 conscription cohort. *Soc Sci Med*. 2007; 65:1410–9. PMID: [17582667](#)
4. Lawlor DA, Batty GD, Clark H, McIntyre S, Leon DA. Association of childhood intelligence with risk of coronary heart disease and stroke: findings from the Aberdeen Children of the 1950s cohort study. *Eur J Epidemiol*. 2008; 23:695–706. doi: [10.1007/s10654-008-9281-z](#) PMID: [18704700](#)
5. Batty GD, Mortensen EL, Nybo Andersen AM, Osler M. Childhood intelligence in relation to adult coronary heart disease and stroke risk: evidence from a Danish birth cohort study. *Paediatr Perinat Epidemiol*. 2005; 19:452–9. PMID: [16269073](#)
6. Batty GD, Shipley MJ, Mortensen LH, Gale CR, Deary IJ. IQ in late adolescence/early adulthood, risk factors in middle-age and later coronary heart disease mortality in men: the Vietnam Experience Study. *Eur J Cardiovasc Prev Rehabil*. 2008; 15:359–61. doi: [10.1097/HJR.0b013e3282f738a6](#) PMID: [18525394](#)
7. Hart CL, Taylor MD, Smith GD, Whalley LJ, Starr JM, Hole DJ, et al. Childhood IQ and cardiovascular disease in adulthood: prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies. *Soc Sci Med*. 2004; 59:2131–8. PMID: [15351478](#)
8. Kajantie E, Raikonen K, Henriksson M, Leskinen JT, Forsen T, Heinonen K, et al. Stroke is predicted by low visuospatial in relation to other intellectual abilities and coronary heart disease by low general intelligence. *PLoS One*. 2012; 7:e46841. doi: [10.1371/journal.pone.0046841](#) PMID: [23144789](#)
9. Ariansen I, Mortensen L, Igland J, Tell GS, Tambs K, Graff-Iversen S, et al. The educational gradient in coronary heart disease: the association with cognition in a cohort of 57 279 male conscripts. *J Epidemiol Community Health*. 2014.
10. Schmidt M, Johannesdottir SA, Lemeshow S, Lash TL, Ulrichsen SP, Botker HE, et al. Cognitive test scores in young men and subsequent risk of type 2 diabetes, cardiovascular morbidity, and death. *Epidemiology*. 2013; 24:632–6. doi: [10.1097/EDE.0b013e31829e0ea2](#) PMID: [23863323](#)
11. Graner M, Varpula M, Kahri J, Salonen RM, Nyyssönen K, Nieminen MS, et al. Association of carotid intima-media thickness with angiographic severity and extent of coronary artery disease. *Am J Cardiol*. 2006; 97:624–9. PMID: [16490425](#)
12. Zuo G, Zhang M, Jia X, Zheng L, Li Y, Zhao H, et al. Correlation Between Brachial-Ankle Pulse Wave Velocity, Carotid Artery Intima-Media Thickness, Ankle-Brachial Index, and the Severity of Coronary Lesions. *Cell Biochem Biophysics*. 2014.

13. Fowkes FG, Murray GD, Butcher I, Heald CL, Lee RJ, Chambless LE, et al. Ankle brachial index combined with Framingham Risk Score to predict cardiovascular events and mortality: a meta-analysis. *JAMA*. 2008; 300:197–208. doi: [10.1001/jama.300.2.197](https://doi.org/10.1001/jama.300.2.197) PMID: [18612117](https://pubmed.ncbi.nlm.nih.gov/18612117/)
14. Den Ruijter HM, Peters SA, Anderson TJ, Britton AR, Dekker JM, Eijkemans MJ, et al. Common carotid intima-media thickness measurements in cardiovascular risk prediction: a meta-analysis. *JAMA*. 2012; 308:796–803. doi: [10.1001/jama.2012.9630](https://doi.org/10.1001/jama.2012.9630) PMID: [22910757](https://pubmed.ncbi.nlm.nih.gov/22910757/)
15. van den Oord SC, Sijbrands EJ, ten Kate GL, van Klaveren D, van Domburg RT, van der Steen AF, et al. Carotid intima-media thickness for cardiovascular risk assessment: systematic review and meta-analysis. *Atherosclerosis*. 2013; 228:1–11. doi: [10.1016/j.atherosclerosis.2013.01.025](https://doi.org/10.1016/j.atherosclerosis.2013.01.025) PMID: [23395523](https://pubmed.ncbi.nlm.nih.gov/23395523/)
16. Roberts BA, Batty GD, Gale CR, Deary IJ, Parker L, Pearce MS. IQ in childhood and atherosclerosis in middle-age: 40 Year follow-up of the Newcastle Thousand Families Cohort Study. *Atherosclerosis*. 2013; 231:234–7. doi: [10.1016/j.atherosclerosis.2013.09.018](https://doi.org/10.1016/j.atherosclerosis.2013.09.018) PMID: [24267233](https://pubmed.ncbi.nlm.nih.gov/24267233/)
17. Gale CR, Deary IJ, Fowkes FG, Batty GD. Intelligence in early adulthood and subclinical atherosclerosis in middle-aged men: the Vietnam Experience Study. *J Epidemiol Community Health*. 2012; 66:e13. doi: [10.1136/jech.2010.109835](https://doi.org/10.1136/jech.2010.109835) PMID: [21558481](https://pubmed.ncbi.nlm.nih.gov/21558481/)
18. Calvin CM, Deary IJ, Fenton C, Roberts BA, Der G, Leckenby N, et al. Intelligence in youth and all-cause-mortality: systematic review with meta-analysis. *Int J Epidemiol*. 2011; 40:626–44. doi: [10.1093/ije/dyq190](https://doi.org/10.1093/ije/dyq190) PMID: [21037248](https://pubmed.ncbi.nlm.nih.gov/21037248/)
19. Sonne-Holm S, Sorensen TI, Jensen G, Schnohr P. Influence of fatness, intelligence, education and sociodemographic factors on response rate in a health survey. *J Epidemiol Community Health*. 1989; 43:369–74. PMID: [2614328](https://pubmed.ncbi.nlm.nih.gov/2614328/)
20. Batty GD, Deary IJ, Macintyre S. Childhood IQ in relation to risk factors for premature mortality in middle-aged persons: the Aberdeen Children of the 1950s study. *J Epidemiol Community Health*. 2007; 61:241–7. PMID: [17325403](https://pubmed.ncbi.nlm.nih.gov/17325403/)
21. Deary IJ, Gow AJ, Pattie A, Starr JM. Cohort profile: the Lothian Birth Cohorts of 1921 and 1936. *Int J Epidemiol*. 2012; 41:1576–84. doi: [10.1093/ije/dyr197](https://doi.org/10.1093/ije/dyr197) PMID: [22253310](https://pubmed.ncbi.nlm.nih.gov/22253310/)
22. Deary IJ, Gow AJ, Taylor MD, Corley J, Brett C, Wilson V, et al. The Lothian Birth Cohort 1936: a study to examine influences on cognitive ageing from age 11 to age 70 and beyond. *BMC Geriatrics*. 2007; 7:28. PMID: [18053258](https://pubmed.ncbi.nlm.nih.gov/18053258/)
23. Deary IJ, Whalley LJ, Starr JM. A lifetime of intelligence: follow-up studies of the Scottish Mental Surveys of 1932 and 1947. Washington, D.C.: American Psychological Association, 2009.
24. Alexandrov A. Cerebral vessels. In: Zwiebel WJ, Pellerito JS, editors. *Introduction to vascular sonography* 5th ed. Philadelphia: Elsevier Saunders; 2005. p. 107–31.
25. Wardlaw JM, Lewis S. Carotid stenosis measurement on colour Doppler ultrasound: agreement of ECST, NASCET and CCA methods applied to ultrasound with intra-arterial angiographic stenosis measurement. *Eur J Radiol*. 2005; 56:205–11. PMID: [15964165](https://pubmed.ncbi.nlm.nih.gov/15964165/)
26. Haller C, Schulz J, Schmidt-Trucksass A, Burkardt H, Schmitz D, Dickhuth HH, et al. Sequential based analysis of Intima-Media Thickness (IMT) in common carotid artery studies. *Atherosclerosis*. 2007; 195:e203–9. PMID: [17720168](https://pubmed.ncbi.nlm.nih.gov/17720168/)
27. Galobardes B, Smith GD, Lynch JW. Systematic review of the influence of childhood socioeconomic circumstances on risk for cardiovascular disease in adulthood. *Ann Epidemiol*. 2006; 16:91–104. PMID: [16257232](https://pubmed.ncbi.nlm.nih.gov/16257232/)
28. Office of Population Censuses and Surveys. *Classification of occupations 1980*. London: HMSO; 1980.
29. Starr JM, Taylor MD, Hart CL, Davey SG, Whalley LJ, Hole DJ, et al. Childhood mental ability and blood pressure at midlife: linking the Scottish Mental Survey 1932 and the Midspan studies. *J Hypertens*. 2004; 22:893–7. PMID: [15097227](https://pubmed.ncbi.nlm.nih.gov/15097227/)
30. Batty GD, Deary IJ, Schoon I, Gale CR. Mental ability across childhood in relation to risk factors for premature mortality in adult life: the 1970 British Cohort Study. *J Epidemiol Community Health*. 2007; 61:997–1003. PMID: [17933959](https://pubmed.ncbi.nlm.nih.gov/17933959/)
31. Calvin CM, Batty GD, Lowe GD, Deary IJ. Childhood intelligence and midlife inflammatory and hemostatic biomarkers: the National Child Development Study (1958) cohort. *Health Psychol*. 2011; 30:710–8. doi: [10.1037/a0023940](https://doi.org/10.1037/a0023940) PMID: [21604878](https://pubmed.ncbi.nlm.nih.gov/21604878/)